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Dynamical modeling with co-variation between soil organic carbon and bulk density for SOC baseline delineation in paddy fields

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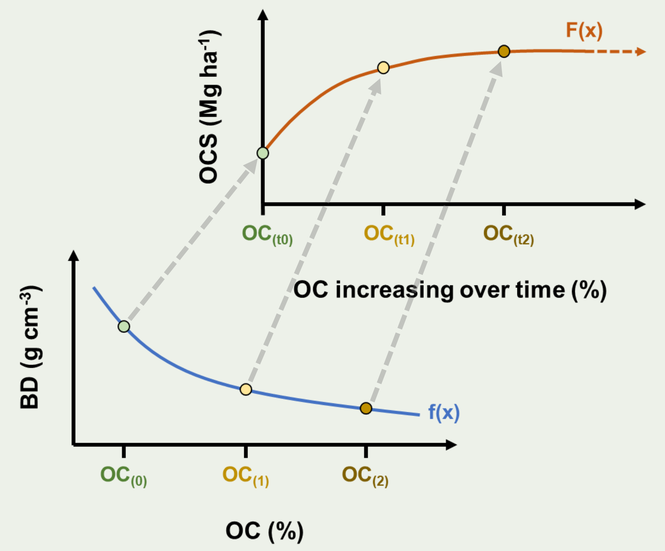
BACKGROUND

The baseline of soil organic carbon (SOC) stock provides a reference for evaluating the contribution of agricultural practices to carbon sequestration. SOC stock, derived from paired observations of organic carbon (OC) and bulk density (BD), is influenced by OC and BD variability and their covariation. A reliable SOC baseline should account for these factors while minimizing BD variation. Establishing SOC baselines is essential for certifying carbon sequestration, but intensive sampling is costly and often impractical in large or heterogeneous regions. In central–southern Taiwan, diverse rice-based systems complicate SOC baseline estimation. To address limited OC–BD data and reduce survey costs, this study developed standardized SOC dynamical models at the field scale in two representative rice-producing regions, Taichung City and Chiayi City, with baseline uncertainty evaluated using the Root Mean Square Error (RMSE).



SOC at different levels (OC_0 < OC_1 < OC_2) are integrated to derive SOC stock values ($F(OC_0)$, $F(OC_1)$, $F(OC_2)$), which representing the temporal accumulation of soil carbon over time (t0, t1, t2).

METHOD

Sample collection and analysis
Data collection

→ Establish the fitting model for OC-BD relationship
f(OC) = BD

→ Apply the best-fit function *f*(OCi) to estimate BDi

$\bar{Z}_{int}$ = h[$\sum_{i=1}^{m} OCi \cdot f(OCi)$]/m

S_{int}^2 = h^2\{$\sum_{i=1}^{m}$[$OCi \cdot f(OCi)$]-m·$\bar{Z}_{int}^2$\}

$\bar{Z}_{int}$, mean SOC stock; S_{int}^2, variation of SOC stock; h, soil depth; OCi and BDi, organic carbon and bulk density data; m, sample size

→ Eliminate the effect of independent variation of BD on baseline estimation

RESULT

Table 1. Information of the study sites.

Site	Management	Area	n	OC	BD	SOC stock
		ha		%	g cm^{-3}	Mg ha^{-1}
Chia-Da	Conventional Ⅰ	0.1	32	0.97 (0.29)	1.56 (0.11)	29.9 (7.8)
	Conventional Ⅱ	0.15	39	1.25 (0.42)	1.55 (0.14)	37.8 (10.6)
	Conventional Ⅲ	0.15	40	1.14 (0.31)	1.57 (0.10)	35.3 (8.6)
Hsing-Da	Conventional	0.4	24	0.62 (0.24)	1.50 (0.27)	17.5 (4.6)
	Organic	0.6	48	0.77 (0.34)	1.54 (0.21)	22.5 (7.2)

Values in parentheses indicate standard deviation

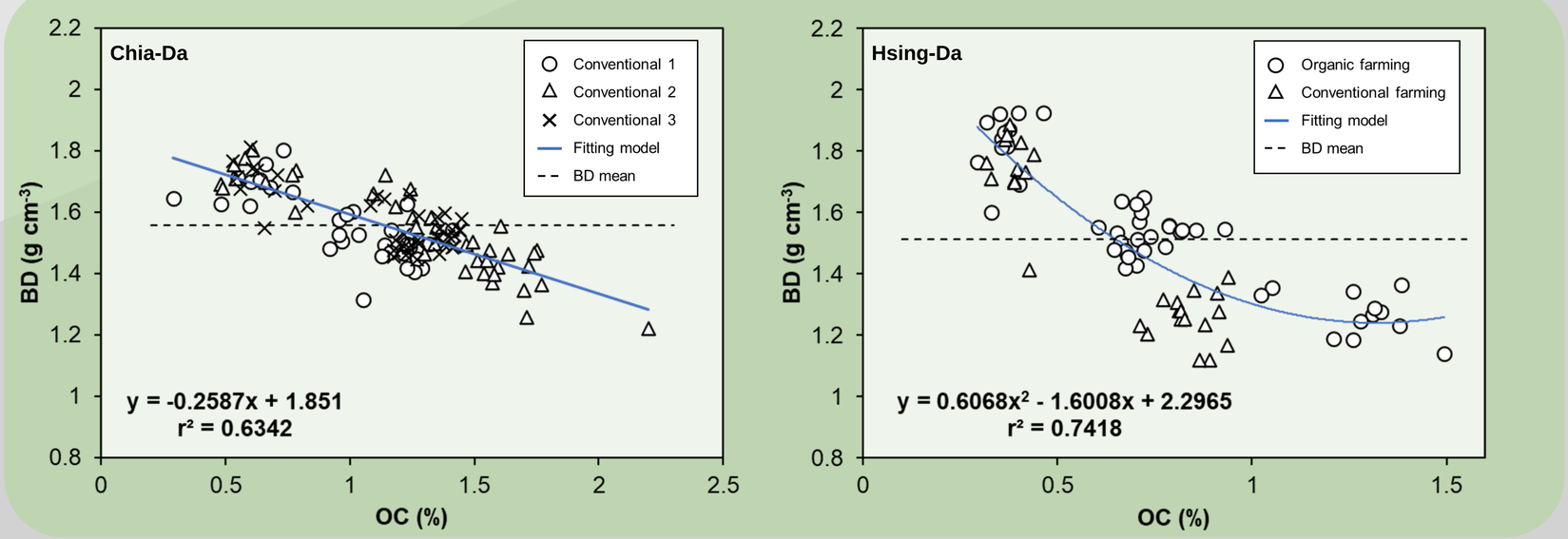


Figure 1. Correlations between SOC and BD.

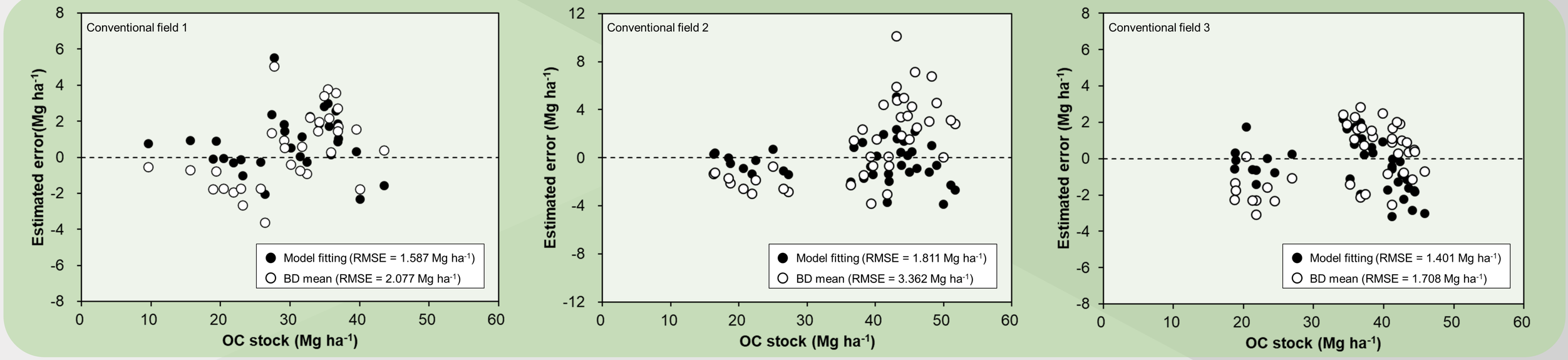


Figure 2. Variability of standardized SOC stock baselines of Chia-Da paddy fields.

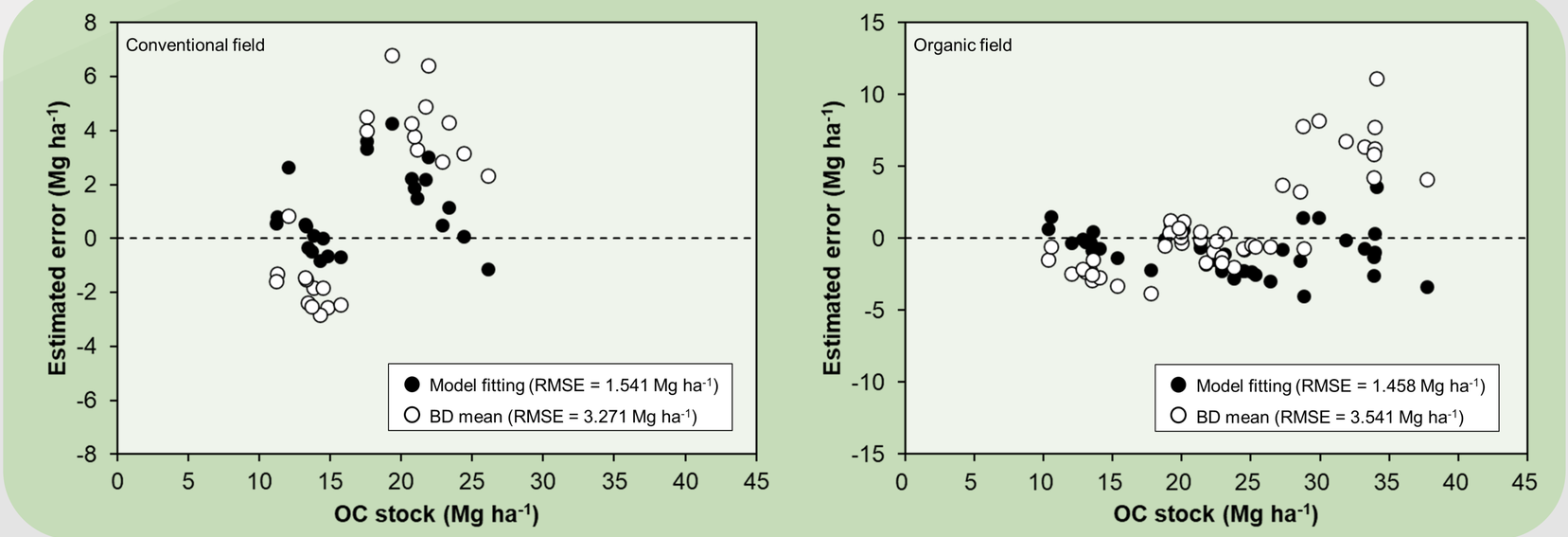


Figure 3. Variability of standardized SOC stock baselines of Hsing-Da paddy fields.

Applying standardization based on the OC–BD correlation for each region effectively reduced the estimation error of standardized SOC stock baselines. In addition, the changes of SOC stock due to OC dynamics in soil would coincide with the baseline functions of SOC stock more well for the Hsing-Da site, reflecting the stronger OC–BD correlations observed in this region.